Online Monitoring of High Density Cultures: A Non-destructive Evaluation Technique

Ryan Johnson, Tim Miskimmin, W.R. Curtis, Chemical Engineering, Penn State.

Background: One major challenge to both lab and industrial scale culturing systems is monitoring of the growth of cultures in a quick and accurate manner. Conventional methods using spectrophotometry are very labor intensive, cause down-time, introduce culture contamination, and cannot measure high-density cultures. We have developed a low-cost optical-electronic sensor using a thin slit path-length and variable LED intensity for the monitoring of low and/or ultra high-density cultures.

Features of the Le-ODinator:

- Low Cost and Efficient Design
- **Non-destructive** monitoring of culture density for nearly any organism
- No modification to current infrastructure
- Reduces **downtime** and potential **contamination** from sampling
- **Real-time** monitoring for feedback control
- Linear correlation to Optical Density (OD) and Biomass Density (gDW/L)
  - OD: 0.2 - 45+
  - gDW/L: 0.1 - 15+
- **Hands-free** algorithm automatically adjusts LED intensity.

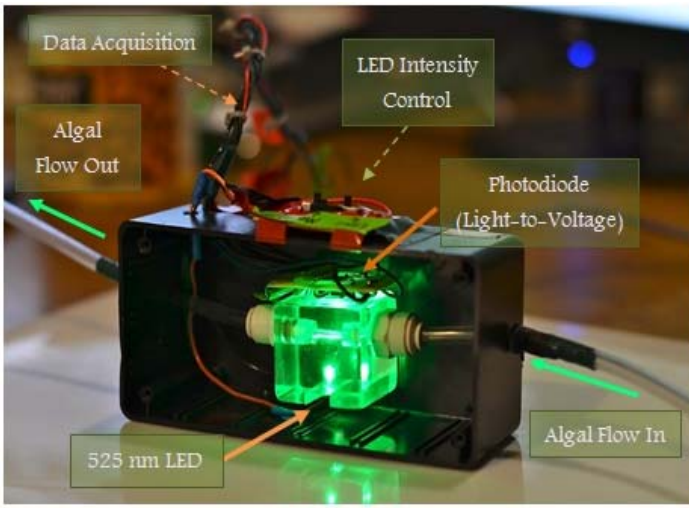

Figure 1: Design of Online Culture Density Sensor

LED cell (growth kinetics): The online sensor measures the OD by shining an LED of the desired wavelength into a flowing culture and measuring the intensity on the other side via a photodiode. As the cells become more concentrated, the culture becomes more opaque to the light. By recording this change in light intensity (and therefore the OD) the culture concentration and growth-rate can be calculated.

Real-Time Monitoring (Data Acquisition and LED Algorithms): The user can either utilize data from the LED cell for feedback control or just log data for analysis in Excel. The online spectrophotometer's LED intensity (mcd) is varied by controlling the current through the LED by varying resistors and voltage, according to Ohm's Law, allowing for various LED intensities to be measured.

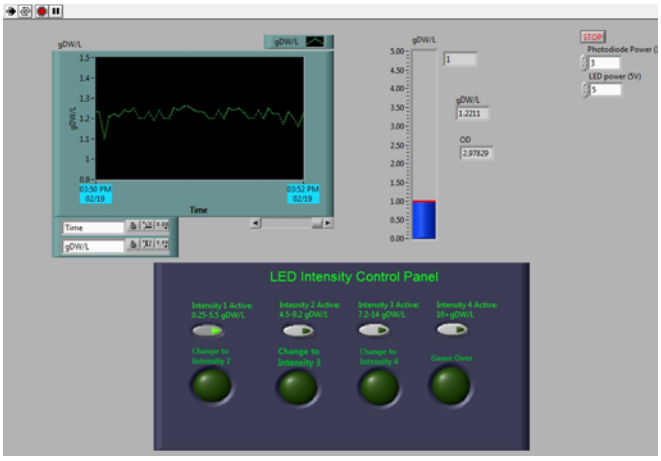

Figure 2: LabVIEW Monitoring of Culture Growth

The rationale behind varying the LED intensity is to enable the measurement of both high-density algal cultures as well as lower density algal cultures. The need for this arises because high-density cultures require a large photon flux to prevent the full attenuation of photons, while the photodiode will become saturated when low-density cultures are measured at that same intensity. Thus, the algorithm automatically lowers the current for low density culture and use high current for high-density culture.

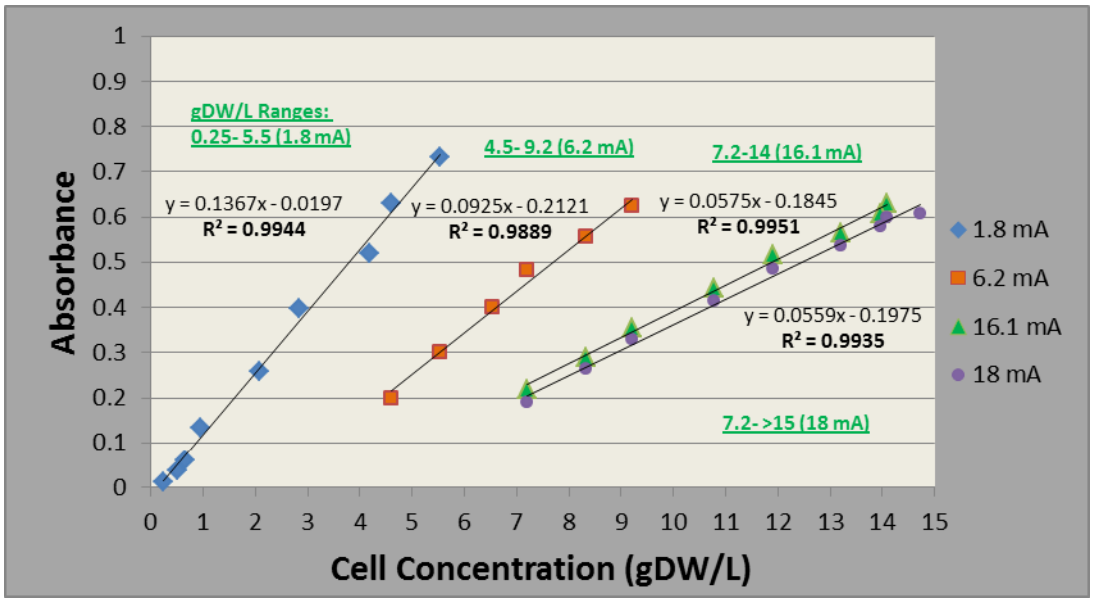

Figure 3: Linear correlation to conventional instruments over a large biomass concentration

Implementation and Evaluation: In-situ analysis of the online sensor was compared with conventional testing methods and showed > 0.99 R^2 correlation over a wide range of cell densities. Repeatable measurements were observed when noise due to air-bubbles was omitted. The data below depicts on-line biomass measurements (green points) correlated to gDW/L (red points) for a growth curve of algae in a 150 mL reactor.

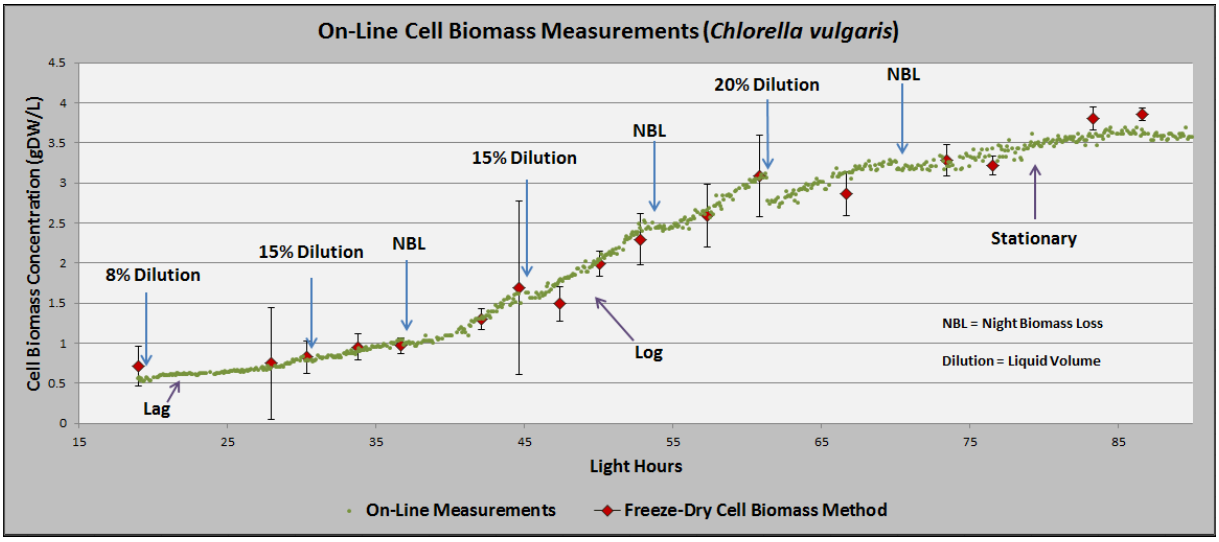

Figure 4: Implementation of sensor for monitoring culture growth